古代地中海の船 : オデュッセウスの舟とアルゴー船

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Ships in the Ancient Mediterranean —The Boat of Odysseus and *Argo*—★

Takako NIWA

古代地中海世界の木造船はどのような工法で建造されていたか。多くの文献や図像が船や造船術の概略は伝えても、その詳細は不明であった。しかし、二十世紀後半の海底考古学の発展によって、長年の謎が解明された。地中海の海底から引き上げられたいくつかの沈没船の残存部分から、それは西欧世界が知る"skeleton-first method"とはまったく逆の "shell-first method"だったことが判明したのである。また、プラトンが語り、「使徒行伝」の聖パウロの難破の件で語られている"hupozomata"は、重要な艤装であることがわかりながら、実際にどこに、どのように装着したのか不明であった。専門家は文献や図像資料にそれらしい証拠を探りながら、船の「外側」にあったという一応の結論を引き出していた。ところが、三段櫂船復元プロジェクト（1987～1990 年）の成功により、それは「内側」に装着する艤装だったことが確認された。こうした近年の新しい発見をもとに、本論は、これまで曖昧であった『オデュッセイア』における「オデュッセウスの舟造り」の一節（5. 228-61）[1]の解明と、『アルゴナウティカ』に描かれる「アルゴー船」のヴァーチャル・モデルの構築を、その艤装や策具を検証しつつ、試みるものである。

I Preface

There are so many descriptions, metaphors and allusions concerning ships and seafaring in Greek poetry and prose writings. The *Iliad*, the most famous epic poem by Homer, tells us the imposing fleets of as many as 1186 ships from all over the land made a grand expedition across the Aegean Sea for Troy, and the *Odyssey*, another epic poem by Homer, depicts a fantastic adventure of Odysseus adrift on the Mediterranean Sea for ten years after the Trojan War. And the *Argonautica* by Apollonius Rhodius is a story of an enterprise of fifty heroes aboard *Argo* going into the unexplored Black Sea to recover the Golden Fleece. And these Greek epic poems inspired Virgil the Roman poet to compose the *Aeneid*.

Without knowledge on the nautical practices which lie behind these literary works, we cannot expect proper understanding and satisfactory appreciation of their passages.

★ This paper is a revision of the one that is to be read as a guest speaker at the international conference, titled "Il Bossolo e la Carta da Navigare Orientamento e Strumentazione Nautica nel Medioevo", to be held on November 21-22, 2003, at Amalfi, Italy. It is newly supplemented by detailed notes and figures.

[1] The numerals in parentheses show the relevant lines in the texts. The four-digit numerals in parentheses in footnotes show the publishing years.

平成 15 年 4 月 30 日受付

II The "skeleton-first method" and the "shell-first method"

Until the middle of the 20th century, when maritime archaeology was brought into the spotlight, we had no idea how the ancient mariners of the Mediterranean built their boats. Although we have numerous general portrayals of ancient boats and ships in literary texts and iconographical representations, we could not infer the method of shipbuilding from them. Yet, the development of maritime archeology brought a new light to the study of early marine civilization. The discovery and investigation of submerged wrecks of the ancient Mediterranean ships has revealed even the way of Mediterranean shipbuilding in antiquity.

In Western Europe when they build wooden boats, they first assemble the keel at the stem and the sternpost. Then, they join ribs or frames to the stringers. On the top of the ribs are joined crossbeams. The planking is constructed after the skeleton of the ship is completed. This is the so-called "skeleton-first method" (Fig.1)[2].

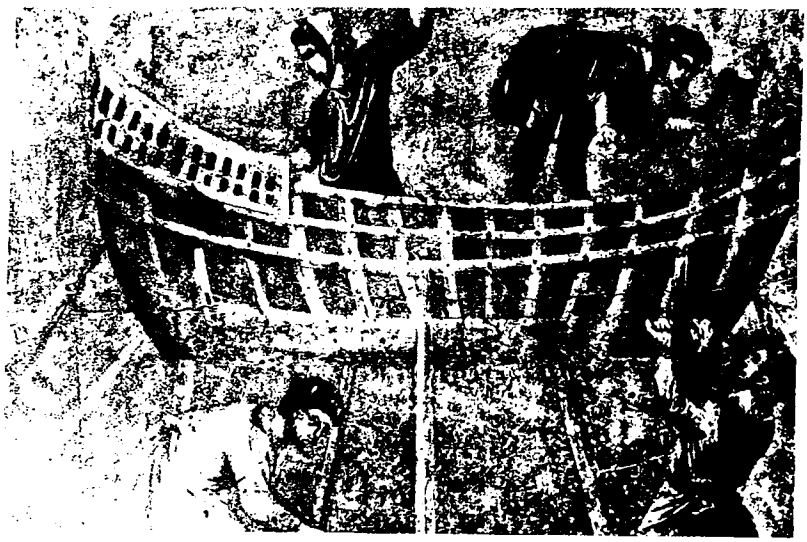


Fig.1 Shipwrights are building the boat in the "skeleton-first method".
This is one of the earliest representation of the method by Paoloda Venezia (1310-58).

But in the ancient remains rescued from the depth of the Mediterranean Sea, we discerned just the reverse way. It was proved by numerous wrecks recovered that their ribs covered the pegged joints of the planking, which was fastened to each other by mortises and tenons (Fig.2, 3,4,5). That is to say, they were constructed by the so-called "shell-first method". It had not been known to modern Western Europe until they were recovered.

By the "shell-first method" they first erected a strong shell of planks by joining edges together closely by mortises and tenons. Then into the finely built shell, either partly or totally, was inserted a complete set of frames, to stiffen the shell tight (Fig.6). In this way of construction, planks made fast not only to frames but also to each other would be less likely to start under surge or any kind of shock during navigation. It was found out that this distinctive method was developed in ancient

[2] This method of construction is characteristic of Northern Europe, particularly Scandinavia, though the time and the place of its origin are obscure. Throughout the age of the wooden ship the "skeleton-first method" prevails among the Western seas. Lionel Casson (1996, p.154) observes that the "building skeleton-first not only permitted infinitely more flexibility in the design of hulls but also the capability of making them far larger and at the same time relatively lighter and stronger."

Phoenicia, Greece and Rome.[3]

Consequently this discovery brought a key phase in the interpretation of the classical literary texts. First of all, the knowledge of the "shell-first method" made the passages 5.228-61 in the *Odyssey* definitely elucidatory which seem to have puzzled translators and commentators.[4] Beginning with the shell by means of mortises and tenons ("harmoniai" [5] in the Greek term), Odysseus made his boat in the standard practice in those days.

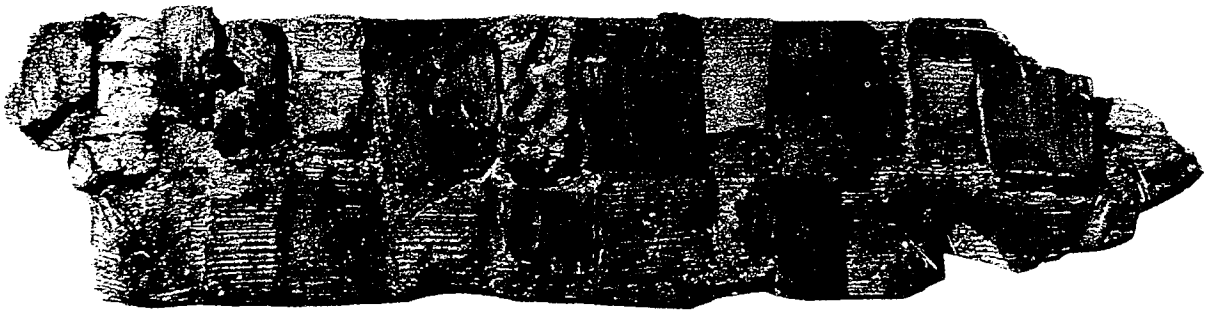


Fig.2 A piece of planking, split lengthwise, from a wreck of the 2nd century B.C. found off Marseilles. The plank is about 6" wide and 2-2 1/4 thick, the mortises are 2 3/8-3 1/8 deep and about 2 1/4 broad, and they stand less than 2" apart.

[3] This method was used in the Middle East until quite recent times and in Japan in the Edo era. The Ulu Burun wreck excavated off the south-west of Turkey during 1984 and 1994 is considered to be the earliest evidence in the 14th century B. C., because in the remnants Mycenaean ceramic and other artifacts were discovered, though the ship was probably not Mycenaean. This method may have originated in Egypt, known as "carvel construction". It is sometimes taken to be identical with the "shell-first method", but not quite the same as that of the East Mediterranean. In the case of the Cheops ship, for instance, which was excavated from an underground ship-shed in front of the Cheops Pyramid in 1954, her hull was built in the "shell-first method", but the planking was fastened not only by mortise and tenon joinery but also by lashings, just as sewn (Fig.7, 8).

[4] Casson (1996), p.35, pp.217-19. Especially the article of pp.217-19 clears the reason why these lines of the *Odyssey* thwarted the Western commentators who thought in terms of traditional Western methods of shipbuilding. A.T. Murry the earlier translator of the *Odyssey*, who did not know the recent outcome of maritime archaeology when he translated it in 1919, has left something uncertain about the boat construction. But A. Heubeck, S. West and J. B. Hainsworth, even the latest commentators of the *Odyssey* (1998) do not develop proper and clear arguments, either.

[5] *Odyssey* 5.248. S. Mark (1991) claims that "harmoniai" here were "cords that held together planks, not mortise-and-tenon joints" and "denote both the dowels that join the planking and the pegs that secured the cords"(p.444). He considers: Odysseus' boat is not a mortised and tenoned boat, but "a sewn boat whose planks were laced together with cords"; the painstaking mortise and tenon joining technique was done away with the collapse of the Mycenaean world; in Homer's age "this technique was replaced by the simpler laced method"(p.445). The persuasive counterargument to his interpretation is Casson's 'Odysseus' boat (*Od.* 5.244-53)' in 1992. Casson and other classical scholars posit that "harmoniai" are mortise and tenon joints and the author of this paper agrees with this opinion.

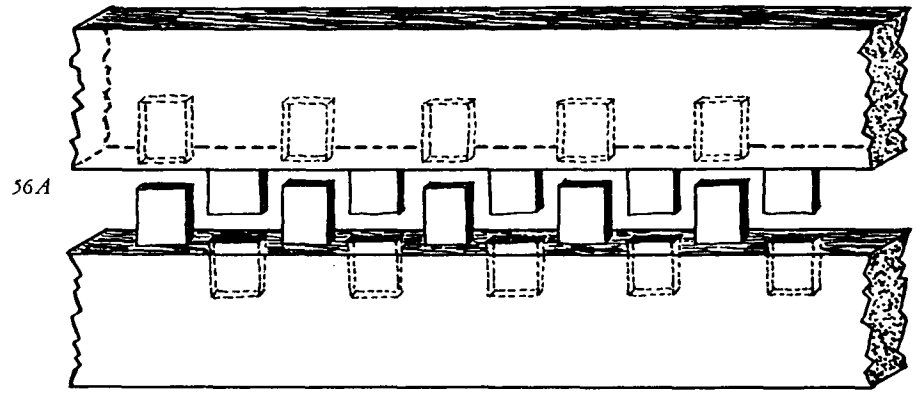
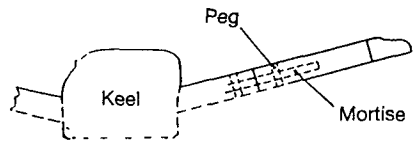


Fig.3 Reconstruction of Fig.2.



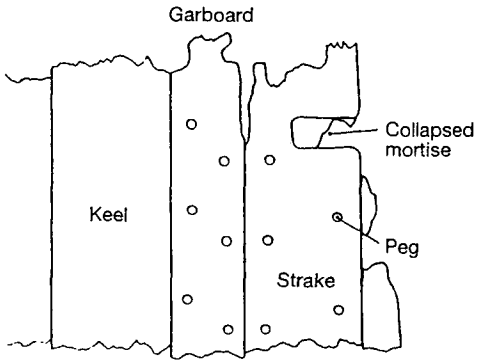


Fig.4 The Ulu Burun wreck remains
(after Wachsmann, 1998: fig.10.2)

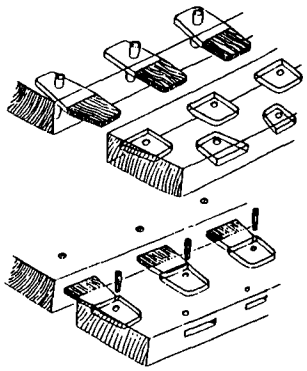


Fig.5 Locked mortise and tenon fastenings
(after Pomey,1997.94)

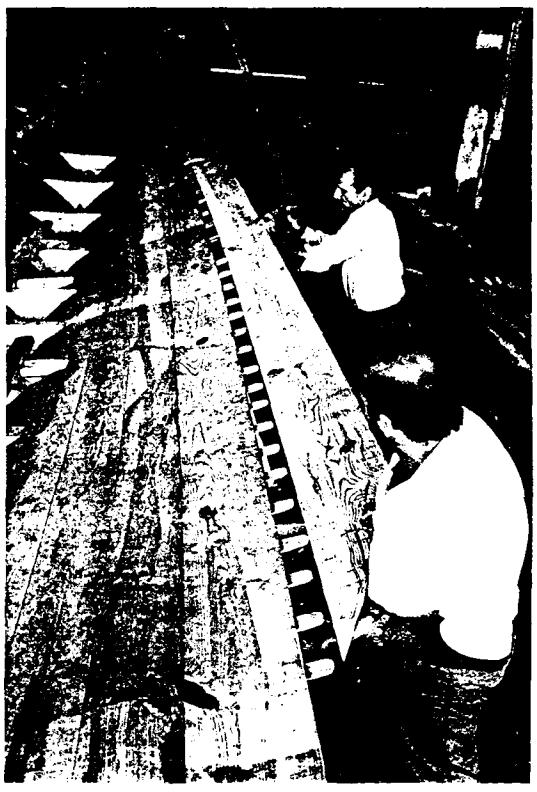


Fig.6 Shipwrights adding a plank as they built up the hull of a replica of the Kyrenia wreck. It was a small merchantman of about 300 B. C. found off Kyrenia on the north coast of Cyprus. The line of close-set mortise and tenon joints is clearly visible.

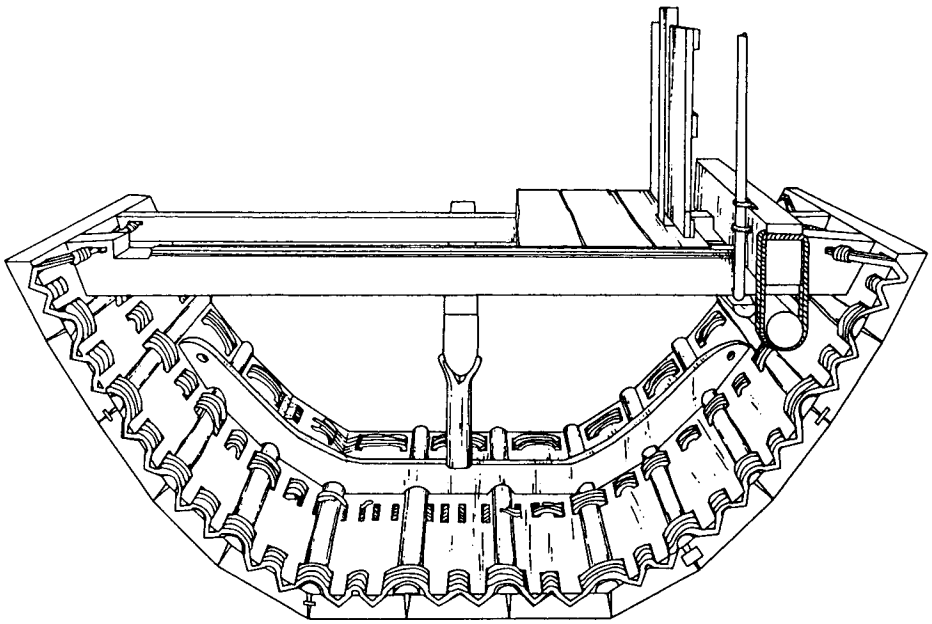


Fig.7　A diagrammatic sectional view of the Cheops ship (after Lipke, 1984: fig.48)

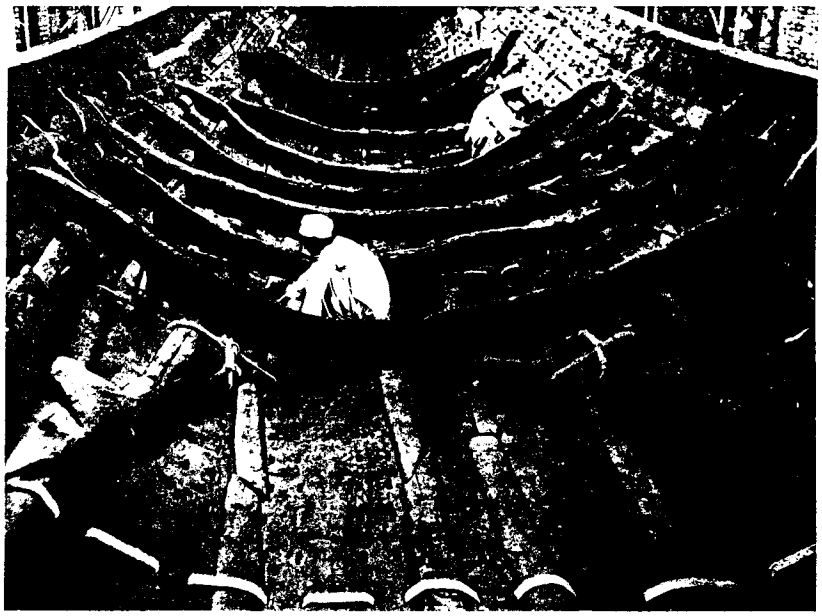


Fig.8　The interior of the Cheops ship with temporary fastenings in place (photo: Paul Johnstone)

III The boat of Odysseus

In the *Odyssey* 5.228-61, Homer depicts how Odysseus, after losing his ship and crew in a storm on the way home from Troy. He landed alone and helpless on the island of Calypso the divine nymph. Calypso took him in and enjoyed his company and kept him there for seven years. The Olympian gods finally forced her to let him go and return to his wife Penelope in Ithaca, his homeland. Calypso helped him build an improvised boat, providing him with the logs and tools.

The poet continues as follows. Odysseus fell twenty trees in all (244), long dry and well seasoned, and cleft them with a bronze axe. He bored them all and fitted them to each other. Then he planed to made planks of them (245). Then he chiseled mortises to hold the tenons locked into place and fitted them to each other (247). He hammered them with pegs and joints, knocking the planks together, and driving home the tenons into the mortises (248). Having built up the shell in this way, he inserted frames, fastened crossbeams, and laid deck planking (252-53). The boat was completed with skillful and elaborate craftsmanship. Improvised as it was, Odysseus' vessel was a genuine boat, with their planks painstakingly jointed to each other, and competently finished in four days (262)[6]. (Fig. 9)

Fig.9 A shipwright finishing up a hull (2nd or 3rd century AD). The skin of planking having been completed, he is now busy adzing a frame to insert in it. The inscription reads "Longidienus pushes ahead on his work".(Ravenna Archaeological Museum)

[6] This Odysseus' vessel has been considered to be a simple raft, for example, by the above mentioned A. T. Murry the earlier translator in the Loeb Classical Library version (see the note 4) and Carol Dougherty the author of *The Raft of Odysseus,* etc. But A. Heubeck, S. West and J. B. Hainsworth (1998), following the new information on maritime archeology through works by Casson (1964. 1996) and J. S. Morrison (1968) argue that Odysseus' vessel is a genuine boat, not a raft. This paper also intends to assert positively that it is not a simple log-raft or rudimentary log-boat at all, but a genuine boat with frame and partial deck, elaborately built by the traditional constructing method. See Casson's detailed report titled 'Odysseus' Boat. (*Od.* V, 244-57)' in 1964 which is the first interpretation of the relevant passages as a genuine boat-building scene and his book in 1996 with an appendix about Odysseus' boat.

After sailing away from Calypso's island[7], Odysseus did not forget to watch the movements of the heavenly bodies and use his "star compass" in his mind to keep his bearing (270-5)[8]. And in addition he had a "wind compass" available in his body. He could know what quarter the wind was in.[9] Odysseus was a skillful shipwright and born mariner.[10] If it had not been for the moody intervention of Poseidon the God of the sea, the boat could have crossed the open sea, and sent him safe to Penelope waiting for him in Ithaca.

Now, I myself tried tentatively making his boat by computer graphics, following the descriptions of the Odysseus' boat in the *Odyssey* 5. 228-61. Naturally Homer's intention was not to record their method of boat construction and his passages are not enough to give coherent information for reconstruction, therefore I owe much to vase-paintings and iconographical reproductions.

Fig.10, 11: What the mortises and the tenons are like. Planks are jointed fast not only to frames but also to each other to keep the hull from starting and depressing under surge or any kind of shock during navigation.

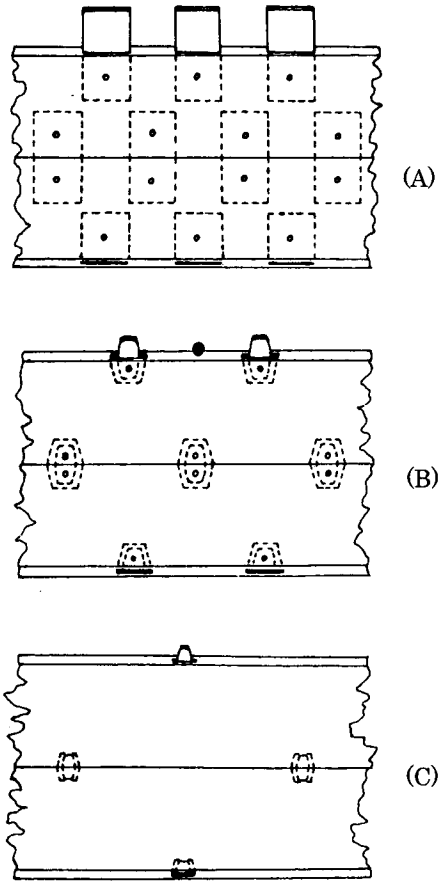


Fig.10 Diagrams illustrating the changes in the nature of mortises and tenons over centuries; (A) mortisea and tenons typical of wrecks dating up to the 1st century AD; (B) mortises and tenons found in a wreck of the 4th century AD; they are smaller, placed further apart, and the tenons fit loosely instead of snugly in the mortises; (C) mortises and tenons found in a wreck of the 7th century AD; they are even smaller and are set even further apart, the tenons fit loosely in the mortises, and they are no longer locked in place by transfixing dowels. (*Ships and seafaring in ancient times*)

[7] It is legendarily told to be a small island of Gozo of the republic of Malta and not far to Ithaca.
[8]. In those days, the long distance voyage continued overnight under good favorable conditions. Good power of observation of stars was requisite for a good seafarer. See the note 23.
[9] It is suggested in the *Odyssey,* 12. 285-90; 14. 455-60, 476-80. Eight elements of a wind compass could be seen on the Tower of the Winds built in the 1st century in Athens.
[10] James Joyce admired that Odysseus was son to Laertes, father to Telemachus, husband to Penelope, lover to Calypso, warrior in Troy and king of Ithaca and that he was a complete man. Then he decided to make *Ulysses* (see Frank Budgen, *James Joyce and the Making of Ulysses*, Indiana UP, 1967, p.16) "Shipwright and mariner" must have been counted.

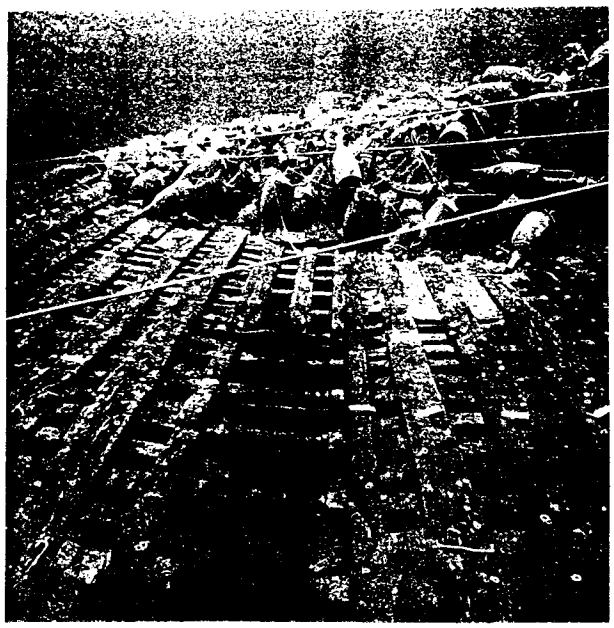


Fig.11 The removal of part of a big Roman merchantman of the mid 1st century BC. The wood underneath was perfectly preserved. Visible are the line of frames, consisting of alternate floor timbers that cross the whole bottom of the vessel and half frames that curve up from either side of the keel and run over the bottom on either side, and the ceiling, the long timbers that run fore and aft over the frames. The white circles mark the nails that hold the ceiling to the frames, and the white dots mark the treenails that hold the frames to the planking. (*Ships and Seafaring in ancient times*)

Fig.12: The vertical section of the tentative boat of Odysseus. The poet tells us that Odysseus finished up the hull so wide just as the beamy hold of a broad merchantman (249-51). After making a broad shell he set to place the deck on it (252-53), and as usual in those days the deck did not cover the whole length from bow to stern[11]. Greek poets often use the words of "hollow" or "capacious" as one of the epithets of seagoing ships.They conceivably intend to emphasize the feature of an extension in length and width of the deckless hull[12]. Their large capacity of the beamy

[11] There is no sign of an overall deck in Homer's ship. As one of the evidences, in Odysseus' shipwreck when the mast fell, "all the tackle was thrown into the bottom of the ship"(12. 410-11). This passage suggests that his boat had no overall deck. She had, if any, a quarterdeck. A passage of the *Odyssey* (13. 73-74) tells that the men of Alcinous spread a rug and a sheet in the quarterdeck for Odysseus to sleep soundly and they sent him safe to the land of Ithaca. Still more, though there was some anachronism in his interpretation, Thucydides living in the 5th century B. C. asserted that Homeric ships were deckless (1. 10. 14). As one more salient evidence, there is a wall painting with a flotilla of ships from the West House at Akrotiri, Thera (Fig.13), It belongs to the 16th century B. C. In this fresco painting the oarsmen are rowing, leaning over the gunwale, with their arms extending full. It evidently shows that the ships were not provided with overall decks and their positions were very low.

[12] In Homeric lines there are three kinds of epithets to express the capacious room of hull. "Glaphyre" is used 40 times in the *Iliad* and 22 times in the *Odyssey*. "Koile" 21 times in the *Iliad* and 19 times in the *Odyssey*. ("Koile" is 1 time in the line 689 of the *Works and Days* by Hesiod, too.) "Megaketes" 2 times in the *Iliad* (see Morrison, 1968, p.45). Liddle and Scott gives their meanings in *An Intermediate Greek-English Lexicon*: "Glaphyre"; hollow, hollowed, of ships, in Homer: "koile"; hollow, hollowed, epithet of ships, which in early times were hollowed out of trees: "megaketes"; great hollow, of a ship, with large hull. And they are almost the

bottom of not only the merchantman but also the warship was probably a constant marvel to those who saw or heard or used them[13]. It was not until the 5th century B.C. that the complete deck appeared on the Mediterranean ships.[14]

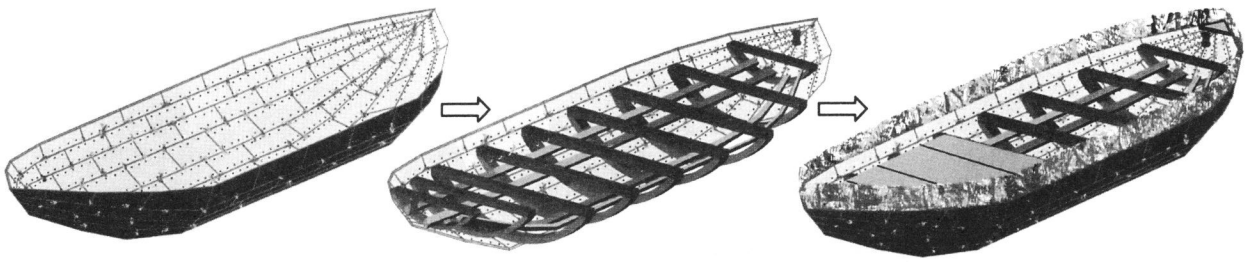


Fig.12　The vertical section of the Odysseus' tentative boat. (with an assistance of Nautical Training Systems)

Fig.16: The view in the profile of the boat completed. It has long gunwales, a mast, a yardarm, a sail and a rudder at the port. Makeshift ropes are made from papyri or willows and more reliable ropes are from leathers.[15] It has no keel. The joints to hold the planking together is mainstay. "Odysseus fenced in the whole from stem to stern with willow withes to be a defense against the waves and strewed much brush thereon"(256-67) [16]. In the earliest days they caulked the seams with moss and osiers and pith of various plants, or sometime with hair.

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same in *A Greek-English Lexicon with revised supplement* in 1996. The interpretation into "hollow", which is etymologically the same as "hole" is unsatisfactory or surely irrelevant. As mentioned above, Greek boats or Mediterranean boats were already competently sophisticated from earlier times, the middle Bronze Age in 2000-1500 B. C. They were not so primitively crude at all as canoes hollowed out of trees or as simple canoe-like boats or log-boats. "Hollow" in English translation and "uturona" in almost all Japanese translations of these epithets have no connotation whatsoever of "beamy", "large", "extensive", "spacious" or "roomy". Moreover in "uturona" in Japanese translation there is some implication of a phantom ship in a ghost story. In *Heikemonogatari* there appears an "uturobune" or "utuobune" which is a synonym of "uturona hune" and just means a canoe-like boat hollowed out of the trees. *A Commentary on Homer's Odyssey* (p.169) has a brief mention about "megaketes" in the different context and also explains the connection with a "hollow ship". Any way "a hollow ship" in English translation could tell the decklessness of a ship at least, but maybe nothing more.

[13] The warship was a light "long ship" (Fig.14) in order to be speedy and accommodate the necessary oarsmen, while the merchantman was a "round ship"(Fig.15), rounded off deep hold to carry a lot of cargoes.

[14] Even the triremes that were very active at the Persian War were not completely decked. In the history of Greek ships overall decks appeared only after the naval battle of Salamis (Morrison, 1968, p.15). But there is some ground to suppose that there were some warships with a kind of continuous deck which linked the forecastle and poop for the accommodation of hoplites and archers (Morrison, 1968, p.161). Anyway, until Salamis, the decks had been simply laying boards and not watertight.

[15] *Odyssey*, 21. 390-391

[16] According to the translation by A. T. Murry in the Loeb version. Casson in his 'Odysseus' Boat (*Od.* 5. 244-57)'(1995, p.219) asserts this brush is "one final minor crux". Some scholiasts suggest this brush was ballast. But "the skin of dark wine and a great one of water and provisions" (265-66) given by Calypso could be of more use as ballast. Casson himself observes: "Odysseus must have strewn a layer of twigs or branches over the bottom": "it was a duckboard to keep Odysseus' feet out of the water that inevitably collects in the bilge of a wooden boat", however, his opinion seems to be lack of persuasiveness. S. Mark has doubts about caulking (p.444), but his opinion seems to have no basis, either.

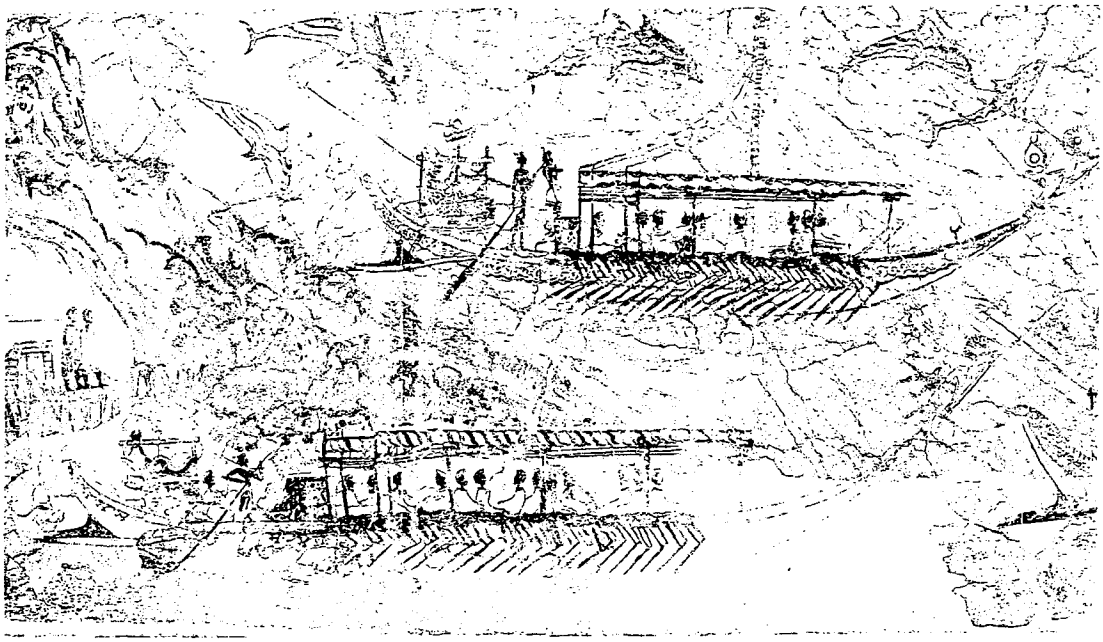

Fig.13 Wall-painting with a flotilla of ships from the West House at Akrotiri, 1550-1500 BC. (Athens, National Archaeology Museum)

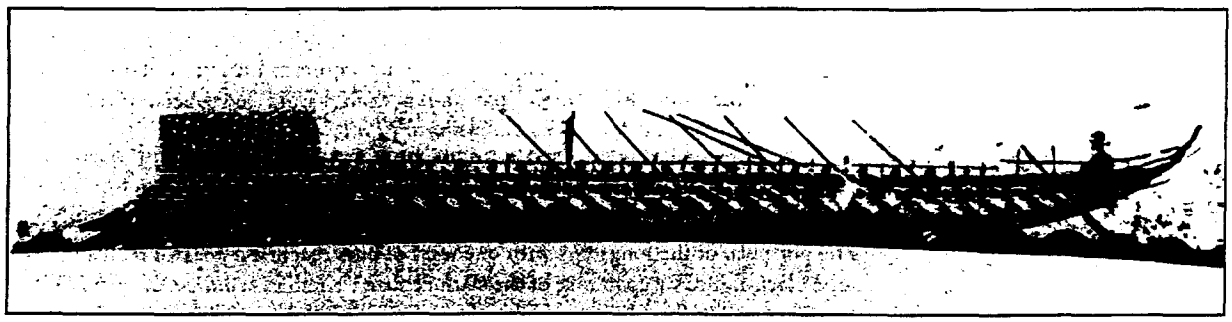

Fig.14 A long ship with 25 oarsmen a side working their oars. Attic black-figure dinos by Exekias (550-530 BC)

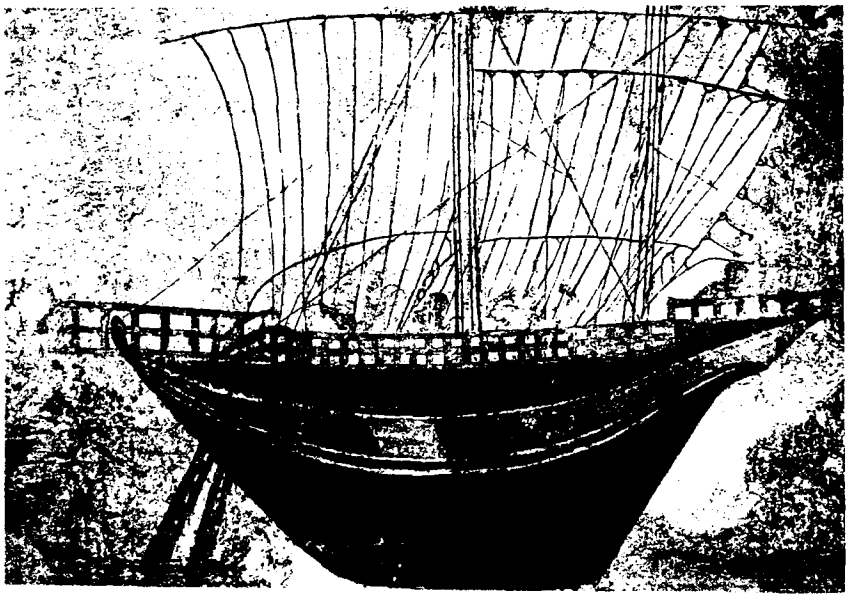

Fig.15 A round ship (550-450 BC) This is the earliest example of a foresail

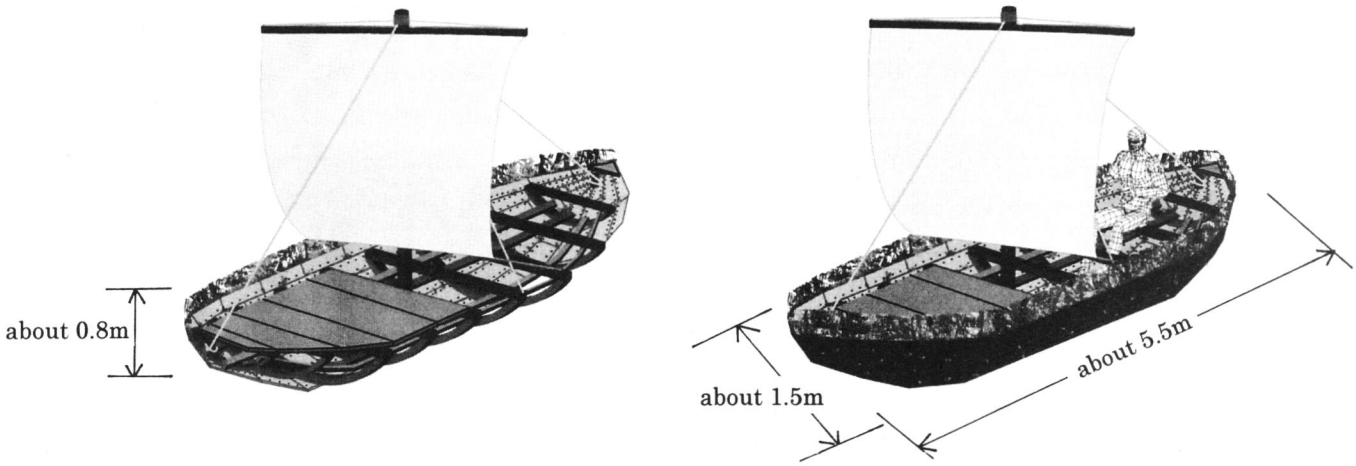

Fig.16 The profile view of the Odysseus' boat completed. (with an assistance of NTS)

IV Building *Argo*

Next I tried building *Argo* on my computer. The myth concerning *Argo* and his crew[17] Argonauts is very old, in all likelihood, of the 13th century B.C., before the Trojan War. But we have no source information other than *Argonautica* by Apollonius Rhodius. Since Apollonius, a learned scholar and poet, lived in the 3rd century B.C.[18], there may as well have been some anachronism and poetical distortion in his epic. It has no sequential depiction of the building procedure and moreover the poetic language was deliberately elliptical so often. Yet *Argo* never fails to give a good impression of swift movement, first under oar, then under sail, a fair breeze filling the canvas. Then, following the lines of the text closely and referring to other evidences in vase-paintings and iconographical descriptions, I managed tentatively to build a virtual *Argo* by the "shell-first method".[19]

Fig.17: The hull and gear. *Argo* was a traditional "pentekontor", a long warship propelled by both oars and sails and steered by the steering oar in the stern. Since the "pentekontor" was swift and most maneuverable, it held the whole Mediterranean in its sway until the appearance of the Greek trireme at the end of the 6th century B.C.[20] The conclusive evidence to support that *Argo* was

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[17] "*Argo* "is exceptionally masculine in gender. But after the 4th century the names of Greek ships were all female. See Casson (1996), p.351.

[18] *The Fourth Pythian Ode* of Pindar (522-438 B. C.) deals with the same theme and narrates Argonautic story in considerable detail, but it was written for the chariot victory and Apollonius surely uses it.

[19] *Argonautica* 2. 80-1 and 613 suggests that *Argo* was built in the "shell-first method" by means of mortises and tenons. Those lines depict that "when shipwrights with their hammers smite ships' timbers to meet the sharp clamps, fixing layer upon layer" and that "Argus knitted *Argo* with bolts".

[20] See Fig. 14. The "pentekontor" is a descendant of the ships represented in the frescoes from Thera (see the note 11). The Greek ships for the Trojan expedition are reasonably guessed to be mainly "pentekontors". According to the catalogue of the ships in the *Iliad* (2. 494-759), each of Philoctetes' seven ships has fifty oarsmen. In the 8th century when Homer lived the normal capital ships were probably the "pentekontors". They were the mainstay of Greek shipping, being used for exploration, settlement, trading and fighting for hundreds of years before 700 B. C. But in the middle of 4th century B. C., triremes, tetrereis ("fours"), pentereis ("fives") and triakontor ("ships with thirty oarsmen") appear to have replaced "pentekontors". The days of the "pentekontors" were gone. In this connection, it can be said that the tetrereis and the pentereis which were probably invented by Phoenicians were the first manifestations of the modern warships.

The trireme came almost exclusively from Athens. When two Athenian travelers were asked in Aristophanese (*Birds* 108) where they came from, they gave a reply "where the fine trireme comes from". Its invention also is assigned to Phoenicians by a fairly reliable legend. The first trireme in Greece was built in Corinthian, and it was through a misunderstanding of Thucydides that he tells (*The History* 1. 11) as if

"pentekontor" is the number of his crew.[21] "Pentekonta" means fifty in Greek and "pentekontor" a ship with fifty oarsmen. At the beginning of the story the poet gives the names one by one of fifty heroes who come from all over the land and of two more, Jason the captain and Argus the shipwright (1. 23- 227). They are fifty-two in all. Indeed, in the "pentekontor" there were usually fifty-two people aboard, fifty as oarsmen and two as officers.[22]

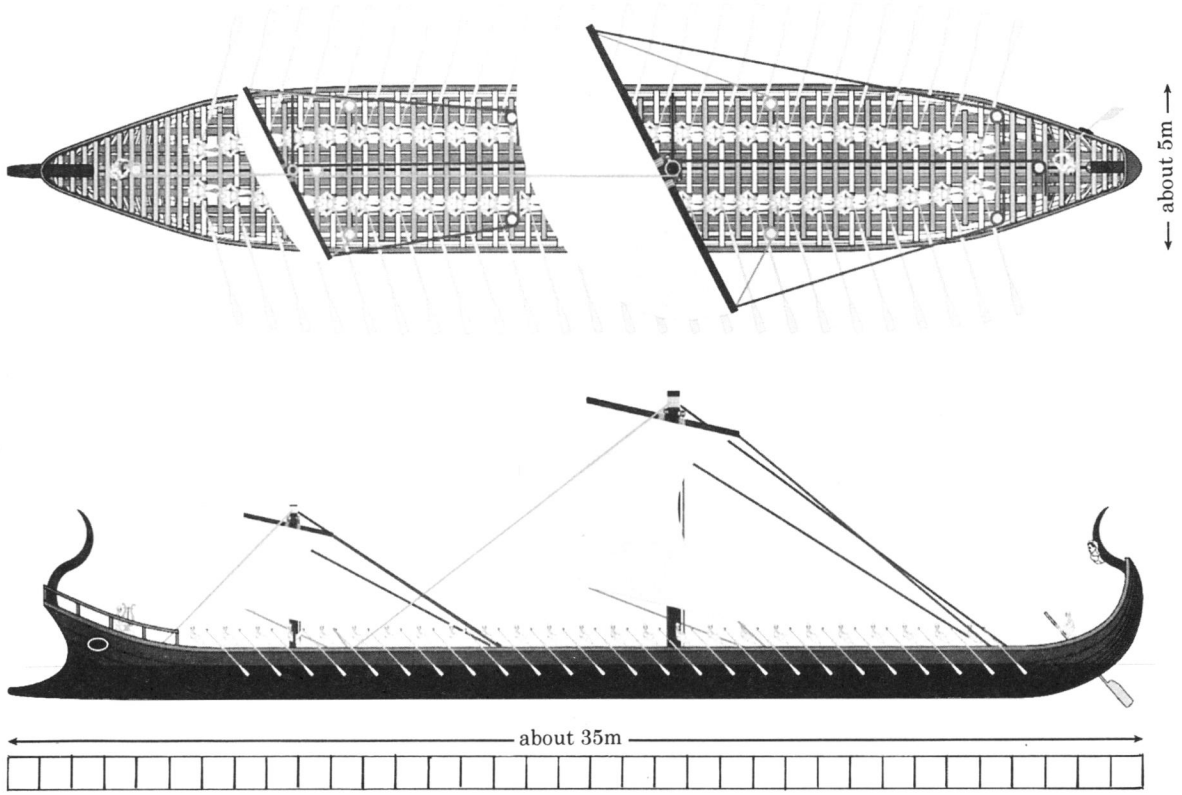

Fig.17 The hull and gear of *Argo.* (with an assistance of NTS)

Among them on board, Tiphys, who is well skilled to foretell the rising wave on the broad sea, and to infer from sun and stars stormy winds and time for sailing, guards the helm of the well-stemmed ship, as a helmsman or coxswain.[23] Argus the shipwright, always ready for refits in need, rows himself as well as Jason the captain does. The heaviest and mightiest Hercules and Ancaeus are given the middle bench as the "key-engine", not by lot. Who is another officer, then? In Argo*nautica* the poet names Orpheus first of all from the list of the crew, although he is not a man of muscle power but a delicate artist. He is a good singer and player of the lyre. Yes, he is certainly not on board as an oarsman. As the text tells that "to the sound of Orpheus' lyre they

Corinthians invented the trireme. Thucydides put an analytical emphasis on maritime affairs and throws light on aspects of Greek maritime history, while Herodotus kept silent.

[21] *The Fourth Pythian Ode* 244-5 asserts that *Argo* is a "pentekontor" and compares it to a snake, taking it presumably as the largest type of ship.

[22] About the crew, Morrison (1968, p.47) tells that the normal capital "pentekontors" are with fifty oarsmen and two officers. In the O*dyssey* 8. 34-6, Alcinous the king of Phaeacia proposed that they would send Odysseus home on a newly built black ship with two and fifty youths. This ship was really a "pentekontor" and the young two were the officers and fifty the oarsmen. She is not called "pentekontor" in Homer's epics. It is probably because in the distant past ships were not called by the name of their types.

[23] As mentioned above in the note 8, in those days the long distance voyage continues overnight under good conditions. *Argo* ran all night with the wind (1. 599), and all the windless night and day they bent to their tireless oars (2. 660-1), or they sped onward in the night without ceasing (2. 945). After the death of Tiphys, Ancaeus took his place.

smote with their oars the rushing sea-water" (1. 540)[24] and "for oarsmen Orpheus touched his lyre and sang in rhythmical song" (1. 570), he was on board to call the tune at the stern as a pitch piper or drummer. If he had not been on, the 50 oars of 50 oarsmen would never have been in a body only to be entangled. His name should be the first among his comrades "shining like gleaming stars among clouds" (1. 239).

According to J. S. Morrison who is one of the leading members of the successful project of hypothetical reconstruction of *Olympias,* the Athenian trireme in 1987-1990 (Fig.18, 19, 20, 21), the hull of a single level "pentekontor" would be about 35 meters, nearly as long as that of a trireme; about 5.5 meters, nearly as wide, for reasons of stability under sail; and the draft less than 1 meter shallow, for reasons of longitudinal stiffness, and there would be wide holds for goods[25]. The trireme was, shortly speaking, a three-level ship in which there were three levels of thwarts or benches for 170 oarsmen.[26] And the maximum speed of the "pentekontor" is estimated at 9.5 knots—just about the same as a modern racing eight. It is calculated theoretically, considering the propulsive power and water resistance.[27]

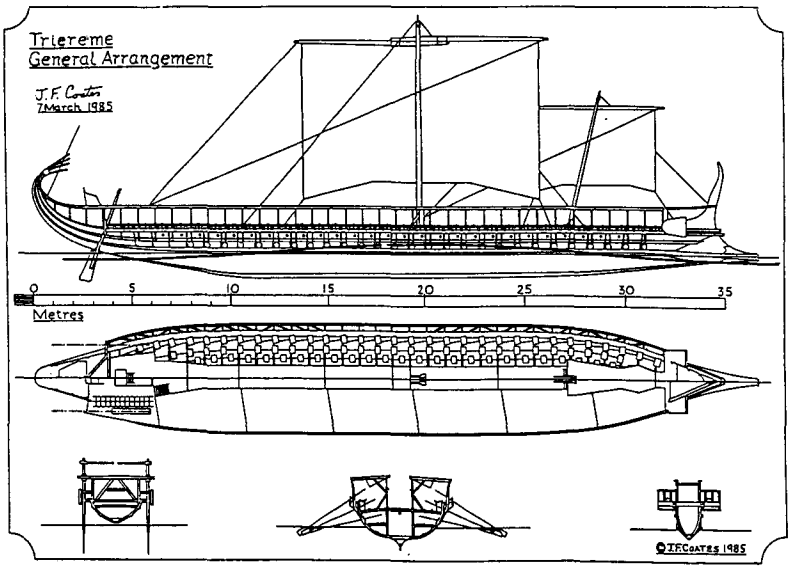

Fig.18 The sketch of the Athenian trireme *Olympias* by J. F. Coates. The hull is designed to survive a wave whose height is 1/ 40th of its length.

[24] All quotations in English from *Argonautica* are from the Loeb Classical Library version translated by R. C. Seaton.

[25] *The Trireme Project*, p.18.

[26] Morrison argues that it seems that two-level "pentekontor" was the immediate precursor of the trireme. In other words, the trireme was, in a sense, a kind of a three-level "pentekontor". About the big problem of the trireme how 170 oarsmen were arranged to be seated, Morrison advances the hypothesis, after many arguments and controversies, which is thought to be most satisfactory, today. He proposes; on each side of the trireme, at the upper bank at the deck level, were seated 32 oarsmen, at the bottom bank slightly below the waterline, 27 oarsmen and at the middle bank not aside but slightly below and inside the upper bank, and above and outside the bottom bank, 27 oarsmen. ('Triereis: The Evidence from Antiquity'. *The Trireme project*, p.18) (Fig.22, 23, 24). In a normal "pentekontor" were seated 25 oarsmen on each side, just at the middle bank of the trireme. Therefore it is not unreasonable to say that the trireme is a kind of a three-level "pentekontor".

[27] See *Engineering in the Ancient World*, p.146. It continues further like this; it is the maximum speed that could be attained by a well-trained crew in good physical condition and could only be kept up for perhaps ten minutes or so; if they had to row over a long distance, they must cut the speed down to just below 9 knots; incidentally, the maximum speed of *Olympias* is about 11.5 knots through practical experiments.

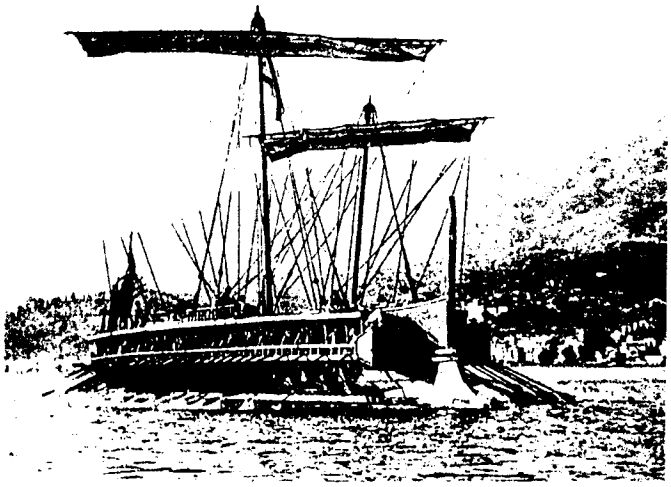

Fig.19 *Olympias* at sea.
(*The Athenian Trireme*)

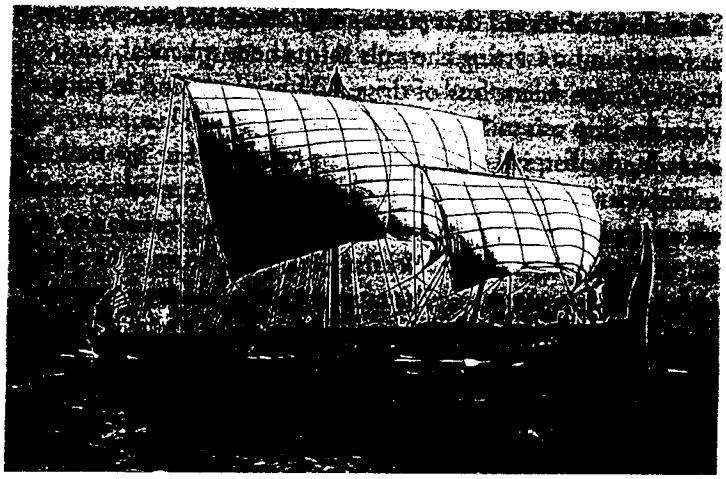

Fig.20 *Olympias* under sail.
(*The Athenian Trireme*)

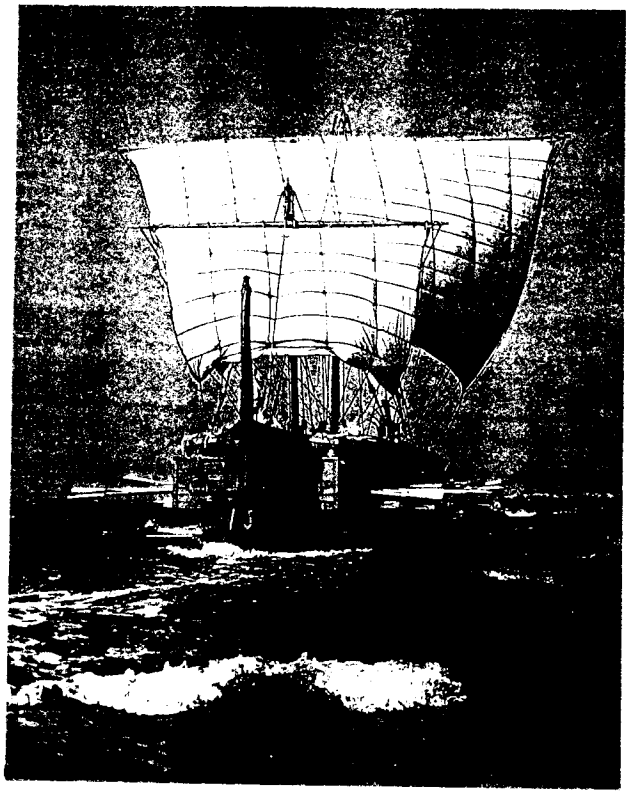

Fig.21 *Olympias* under sail.

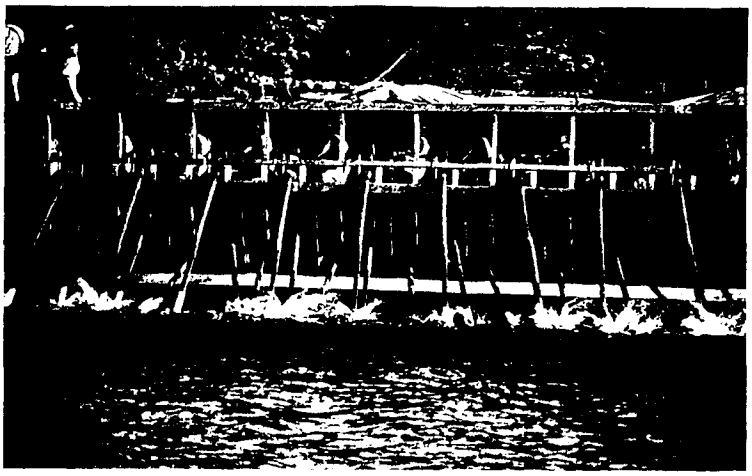

Fig.22 The three-level oars in *Olympias*, separated in the water by less than 30 cm. (*The Athenian Trireme*)

Fig.23 The upper and middle bank rowers of *Olympias*.(*The Athenian Trireme*).

Fig.24 The upper, middle and bottom bank rowers of *Olympias*.(*The Athenian Trireme*)

As the poet describes, he had two square sails[28] and riggings. Forward rigging was not shown, but similar to the main. He had a sturdy keel, but it was not shown either. On each side were fitted twenty-five oars for twenty-five oarsmen at tholepins. The hull was coated black below the waterline, with pine pitch or pine tar or both to make watertight[29]. He had a high curving stern, ram-shaped bow[30], balustraded platform aft and steering oar. The high symmetrically curve of the bow and the stern was one of the most conspicuous features of the earliest Mediterranean ships until the 8th century B.C. (Fig.26, 27, 28, 29)[31] The high curve of the bow was to be against raging waves and that of the stern to keep the balance of the ship. There was "eye" decoration, a sort of talisman[32] and on the middle of the stem was fitted a wooden image of Athena their guardian goddess as an emblem, like the figurehead in the modern times.[33]

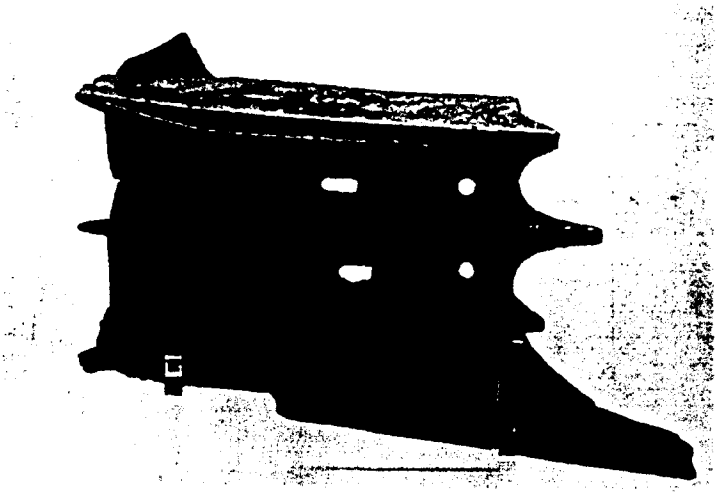

Fig.25 Bronze ram (400 BC) (Piraeus Nautical Museum)

[28] It is not until the 2nd century A. D. that they used a lateen. The number of vessels rigged with lateen sails obviously increased in the second half of the first millennium..

[29] The "black-colored" ("melania") is also one of the outshining epithets given to his ships by Homer: 39 times in the *Iliad* and 43 times in the *Odyssey*. In passing, in the *Works and Days* by Hesiod there is also one expression of "en nei melaine" (636), though it is not translated into English in the Loeb version. While Apollonius never uses the epithet to his epic poem, *Argo* was no doubt coated black with pine pitch, just as Homer's ships. Remember the note 22 in which are introduced phrases from the *Odyssey* which mention "a newly built black "pentekontor". Ships in those days were normally black-colored, having nothing to do with the sinister black or mourning black. Here what I want to make special mention of is the fact that the famous Homeric expression of "wine dark sea" or "violet sea" never appears in *Argonautica* of Apollonius Rhodius, the third century Alexandrian imitator of Homer. Instead, the wild sea is often described with the adjective "black", needless to say the Black Sea. Furthermore the adjective "black" is often used, somehow, before various nouns, as if the text were full of black color.

[30] The keel was terminated forward in a ram or forefoot projection, which was the most salient weapon of Greek oared ships. Ramming was the main offensive tactic in the sea-battles for centuries, while the archers performed a subsidiary role. In the triremes the ram was sheathed in bronze (Fig.25).

[31] The epithets which mean "symmetrical curved" or "high curved" or "twist round at each end" or "upright horns" appear more than 40 times in the Homer's poems. But in *Argonautica* the poet living in the 3rd century did not seem to pay attention to the feature, or he was possibly not familiar with it, and this kind of anachronism can be accountable.

[32] In *Supplicants* by Aeschylus, the poet tells that "the bow has eyes to see the way ahead" (716)

[33] *Iphigeneia at Aulis* by Euripides describes that the emblems of the Greek fleets assembled at Aulis for Troy were at stern (235-76). In those days there was presumably a sort of "stern image". The figurehead at the bow did not appear until the beginning of the 18th century.

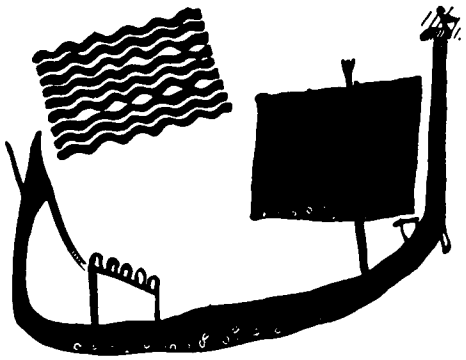

Fig.26　The earliest example of a sail, 3100 BC.

Fig.27　Mesopotamian reed boat, 2300 BC

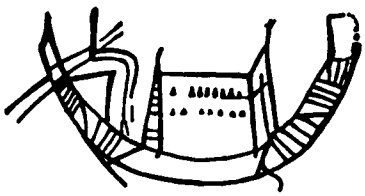

Fig.28　Impression on a seal from Mohenjo-Daro, possibly a bundle raft (after Johnstone, 1980: fig.13.1).

Fig.29　A warship of about 850-800 BC. on a cup found at Eleusis.

Fig.30: The middle section. The deck is not overall, but a quarterdeck.[34] The hull is capacious.[35] There are benches for oarsmen.

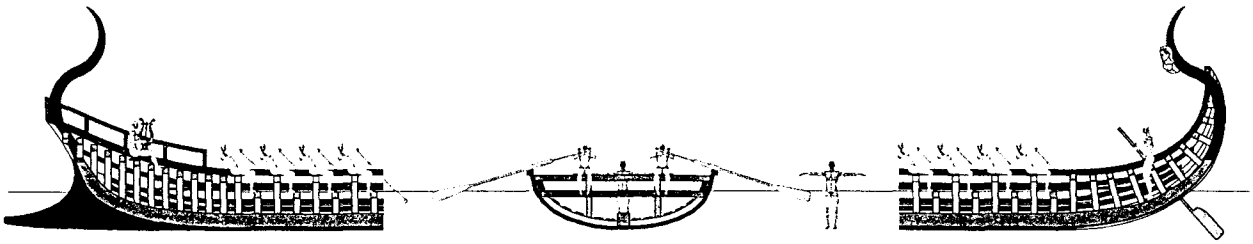

Fig.30 The middle section of *Argo*. (with an assistance of NTS)

Well, finally, after fitting out *Argo*, what did they do? The poet tells; before launching the ship, "they strongly girded the ship with a rope well twisted from within, stretching it tight on each side, in order that the planks might be well compacted by the bolts and might withstand the opposing force of the surge" (1.369-71)[36]. Many classical scholars thought that this rope was "hupozoma" or "hupozomata" in plural.[37] They knew well that the "hupozoma" was the most important to the ship's seaworthiness, as it were, a lifeline of a wooden ship. It headed the lists of gear in the Piraeus Naval Inventories[38] and its fitting to the ship on the active list was provided by law[39] and four were the regulation number of "hupozomata" carried.[40] Nevertheless, the word of "hupozoma" or "hupozomata" is hardly seen in literary texts. Exceptionally Plato mentions it briefly in his works. He writes in the *Laws*[41] that"'entonoi'[42] and hupozomata in ships and taut sinews in the living creature have both the same nature". Then he illustrates a story of the journey of the soul of Er in

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[34] *Argonautica* 4. 1662. See the note 11.

[35] In *Argonautica*, the epithet which is translated into "hollow" by R. C. Seaton in the Loeb version appears 7 times in all: 4 to the ship and 1 to the chest, 1 to the cave and 1 to the mast-crutch. Richard Hunter the translator of the Oxford World's Classics version does not put the epithet to the ship 1 time, but in other cases he also translates it into "hollow" 6 times. See the note 12.

[36] The quotation is from *Argonautica*, translated by R. C. Seaton in Loeb Classical Library version.

[37] R. C. Seaton expressly notes in his Loeb version; "there is probably no allusion to 'hupozomata' (ropes for under-girding) which were carried loose and only used in stormy weather". R. Hunter in his Oxford version translates; " they first of all firmly wrapped a twisted cable around the ship, pulling it taut on both sides, so that the planks would remain held securely in place by the bolts..."(p.12) He probably gave no special consideration to its practical application.

[38] The Naval Inventories were found at Piraeus and show, in a fragmentary state, the annual records of the outgoing Boards of Dockyard Overseers, and give a picture of the organization and practices of the Athenian navy in the fourth century (See *The Age of the Galley*, pp.63-63).

[39] *Inscriptiones Graecae* 1^3, 153:440-425 B.C.. See *The Athenian Trireme*, p.169.

[40] *Inscriptiones Graecae* 2^2,1627.29. See *The Athenian Trireme*, p.169

[41] 945c.

[42] The plural of the noun "entonos", which is derived from the verb "enteino", which means to stretch or strain tight, especially any operation performed with straps or cords.

the *Republic,*[43] with his picture of the universe and says that it is bound with a bond of light "like the hupozomata of trireme". And one more, and probably the most celebrated mentions comes in the account of St. Paul's voyage in the *Acts of the Apostles,* 27. 17. It goes, "when St. Paul and his apostles had taken up, they used helps, undergirding the ship; and, fearing lest they should fall into the quick-sands, strake sail, and so were driven"[44] The word translated here by "undergird" is "hupozomata" in the Greek version of the *Bible*..

But after all we do not have enough to draw a definite image of what "hupozomata" were like and how and where they were fitted and for what they were applied. The word certainly suggests an undergirdle,[45] but its position and rigging was a particular mystery. Through arguments and controversies, scholars and translators and commentators reached a conclusion that "hupozomata" were "ropes long enough to pass round the hull from stem to stern on the *outside*; their object was to subject the *outside* skin to a constricting tension which would keep the structure from working loose under the stress of navigation"[46] "They 'girded' the ship horizontally 'under' the line of the gunwale. A short but powerful loop passed vertically about the stern to furnish a point for anchoring the girding cables at this awkward spot."[47]

V Where are the "hupozomata" ?

I wanted to see with my own eyes such an ingeniously mysterious device of "hupozomata", therefore I looked for them in drawn pictures and iconography in vain. I did not come across things that looked like "hupozomata" anywhere, except only one case. At the critical moment in the *Trojan Women* by Euripides when the wooden horse was being introduced into Troy, the passage depicts that it was "like the black hull of a ship with girdles of woven flax".[48] Morrison explained explicitly "this is an almost certain reference to the rope girdles or swifters ("hupozomata").[49] So I was convinced.[50]

However, a really surprising fact was discovered in the process of building the replica of the Athenian trireme *Olympias*. The project was organized by the experts of archeology, nautical history, Greek classics, architecture, marine engineering and shipbuilders. They repeated controversies and investigations, and concluded that "hupozomata" were not fixed outside, but *inside.*

It was a far cry from what they had believed to be. The "hupozomata" which many people had believed to girdle outside the hull are ascertained to be *inside* the hull and their purpose was to

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[43] 616b-c.
[44] According to the King James version.
[45] Liddell and Scott gives its meaning: "hupozomata"; "braces passed under the hull of a vessel, so as to undergird her"; it comes from "hupozonnumi" which means "undergird". "Gird" is etymologically the same as "girth" and "girdle", both of which mean to encircle round the whole with a girdle or belt.
[46] Morrison (1968), pp.297-98. The Italics is by the author of this paper. G. W. Mooney, the commentator of *Argonautica* also observes; "the 'hupozomata', in the case of the trireme, was stretched lengthwise round the *outside* of the vessel, and so too the rope here." (*Argonautica,* 1912, p.93) The Italics here is also by the author.
[47] Casson (1996), pp.92-3.
[48] The *Trojan Women* translated by Morrison, 537-38.
[49] Morrison (1968), p. 200.
[50] But the wooden horse is not captured with the ropes around the body. It is launching out exultantly into the Trojan castle, like a sailing ship into the open sea with her "hupozomata" fastened. The Trojan people are elated at the victory, not knowing the coming catastrophe after its "launching". This unexpected twist makes the play most striking, otherwise only discursive and insipid.

reduce bending stresses of both of hogging and sagging. They were stretched between points forward and aft, high in the hull section to protect against hogging, just like a hogging truss (Fig.31, 32). So as to protect against bending in the opposite direction, sagging, they had to be fastened low in the hull.[51]

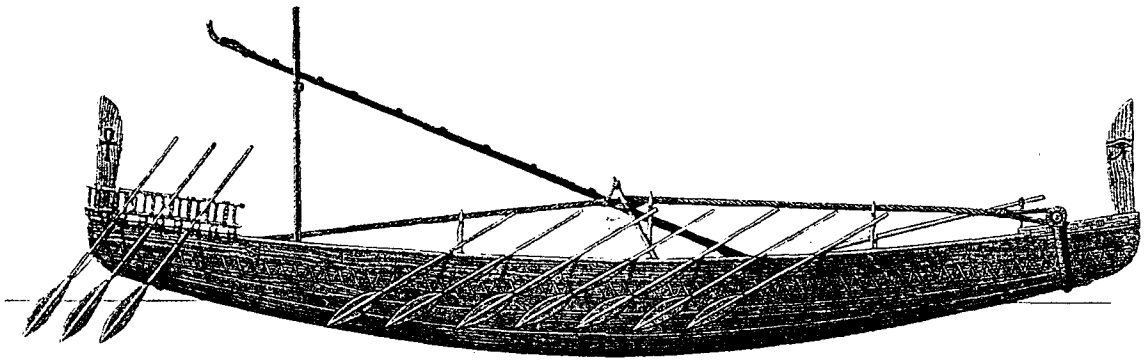

Fig.31 The hogging truss of the Sahura's boat in Egypt. (2490-2340 BC)

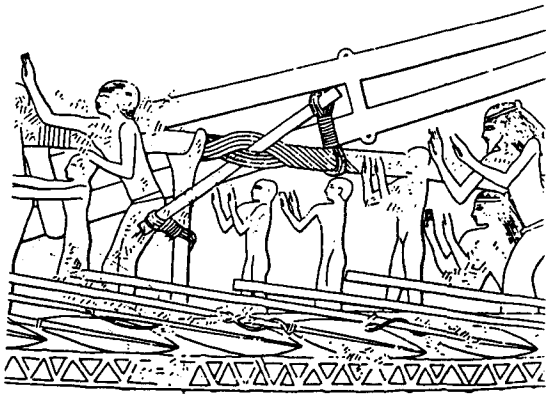

Fig.32 The hogging truss in use from the relief of Sahura's boat. (*Boats*)

Fig.33: The position of "hupozomata" in the mid-section, according to the discovery[52] of the

[51] About the further detailed reports of their findings, see Morrison (1986, 2000), Shaw (1993) and J. G. Landels (2000) and others, while Sean McGrail (2001) has no mention about "hupozomata".

[52] Yet some experts of the ship at our University think that these "hupozomata" seem not to do so much against sagging stress. They expertize that theoretically both hogging and sagging are likely to happen, but actually in the case of the ancient wooden ship with 40 meter length at most and without overall deck, sagging was most unlikely to come about, even with consideration of the scale of wavelength. There seems to have been some sort of device as a "stretcher" to keep them at the proper tension. See Casson (1996), p.92. Our experts presume that all "hupozomata" were not always for the particular protection against the waves or shocks, but usually for the general protection of the fragile hull. Incidentally the "Glossary of terms and Abbreviations" of *the Age of the Galley* defines only that "hypozoma" is in ancient Greek galleys an undergirdling of tightened ropes pulling two points of a hull together to reduce tensile bending stresses. And remember the note by R. C. Seaton (see the note 37). He observed that the "hupozomata" might have been used only during the storm. His

trireme-project members.

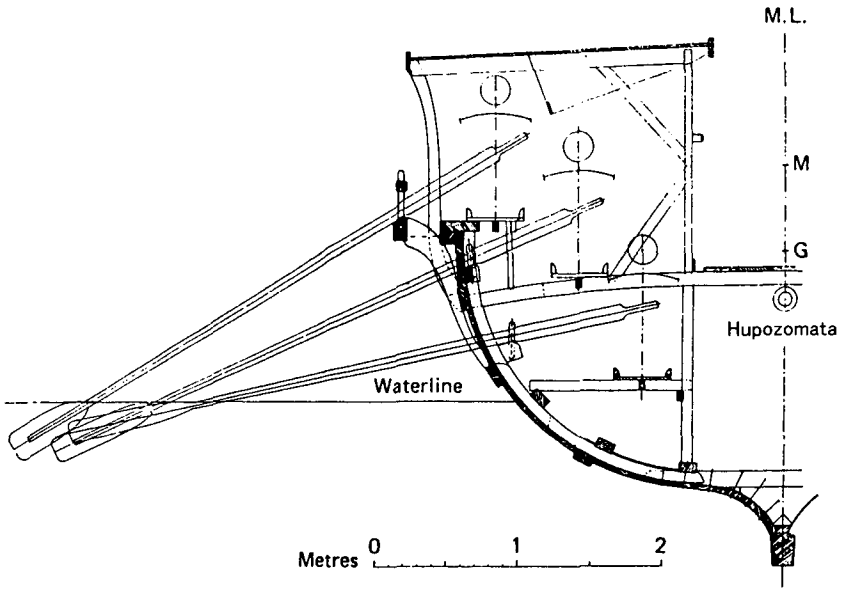

Fig.33 The position of "hupozomata" in *Olympias*. (*The Athenian Trireme*)

Fig.34: The "hupozomata" tightened by deadeyes, lanyards and tackle in the Athenian trireme *Olympias* reconstructed in 1989.

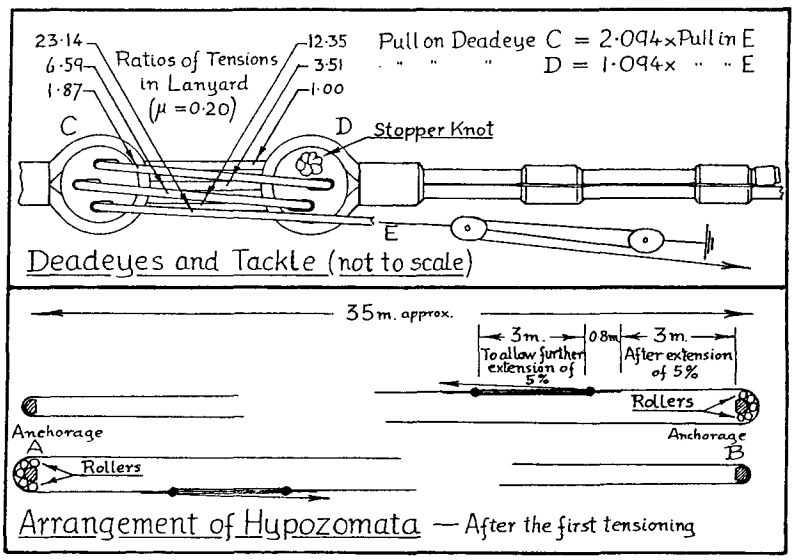

Fig.34 "Hupozomata" tightened by deadeyes, lanyards and tackle. (*The Trireme Project*)

Thus with the "hupozomata" tightened, *Argo* "is borne over the sea swiftly, even as a hawk soaring high through the air commits to the breeze its outspread wings and is borne on swiftly, nor

Seaton (see the note 37). He observed that the "hupozomata" might have been used only during the storm. His opinion tallies with the passage of the wreck of St. Paul in the *Acts*. Some "hupozomata" might have girdled outside the hull vertically just like bundle ropes on the Egyptian papyri boats..

swerves in its flight, poising in the clear sky with quiet pinion."[53]

Well, the "phantomlike hupozomata" are found to be hidden inside and naturally invisible from the outside! Nevertheless some experts of the ship at our University have some doubts about their practical application. And there is still left a question: Is it really out of the question to think that apart from the case of *Olympias,* the name of "hupozomata" originally symbolized the substance? [54]: Is it really improbable that some "hupozomata" girdled outside the hull, whether horizontally or vertically? [55]

Anyway, as Paul Johnstone (1980) had pointed out, "one can safely say, therefore, that some rope to increase the structural strength of the hull was crucial in the Greek period, as swifter, undergird or hogging truss, or all three".[56] And one can safely say that the highly sophisticated ships were built in the Mediterranean Sea from the distant past on and their basic structures were not changed until the medieval period.

Fig.35 Reconstructed of the stern of a Rhodian warship. Bass-relief carved on the site of a cliff at Lindos on Rhodos. (about 200 BC). (*Ships and Boats*)

[53] *Argonautica* 2. 931-35.
[54] The late Emmanuel Nellopoulos, an ex-colonel engrossed in the study of the Greek trireme asserted in his writings (p.279) that *Olympias* was "a model invented by Mr. Morrison and Mr. Coates" and "the ship has a tightly tied wire rope running the length of and around the ship in the place of the usual four hupozomas."
[55] See Fig.35. The two plaited ropes passing vertically down at the stern, all the same, seems to be part of "hupozomata", just as Morrison (1968, p.180) had supposed before the *Olympias* project and Casson had defined. See the note 46.
[56] *The Sea-craft of Prehistory*, p.84. He died in 1976, before the successful reconstruction of the Athenian trireme. See Fig. 36.

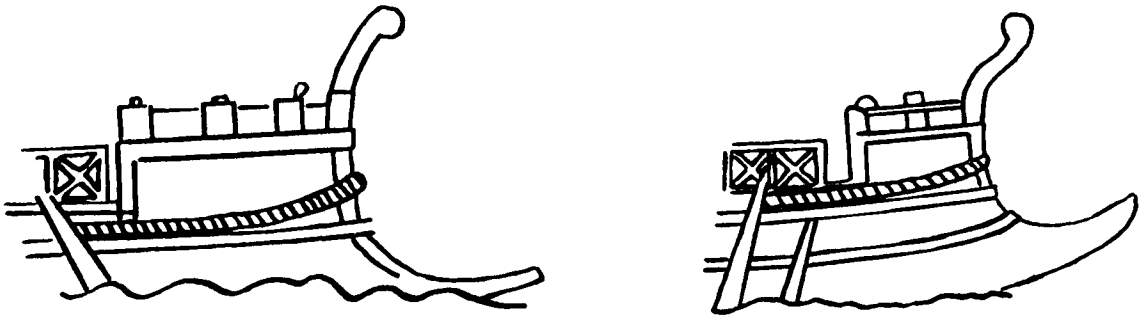

Fig.36 Reconstruction drawings of ships with horizontal straps around one end: from Trajan's Column, Rome and the Triumphal Arch, Orange, France (after Johnstone, 1980: fig.7.18)

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